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AMMUNITION GROUP

WARHEAD AND SPECIAL PROJECTS LABORATORY

MINE AND FUZE SECTION

TECHNICAL MEMORANDUM

NO. DW-285

FEASIBILITY STUDY OF A SIMPLE OFF-ROUTE MINE SYSTEM

BY

J. M. TEITELBAUM

T. WARSHALL

R. W. WILLIS

DATE: AUGUST 1960

ORDNANCE PROJECT: TS1-200 COPY NO. 42 OF 100

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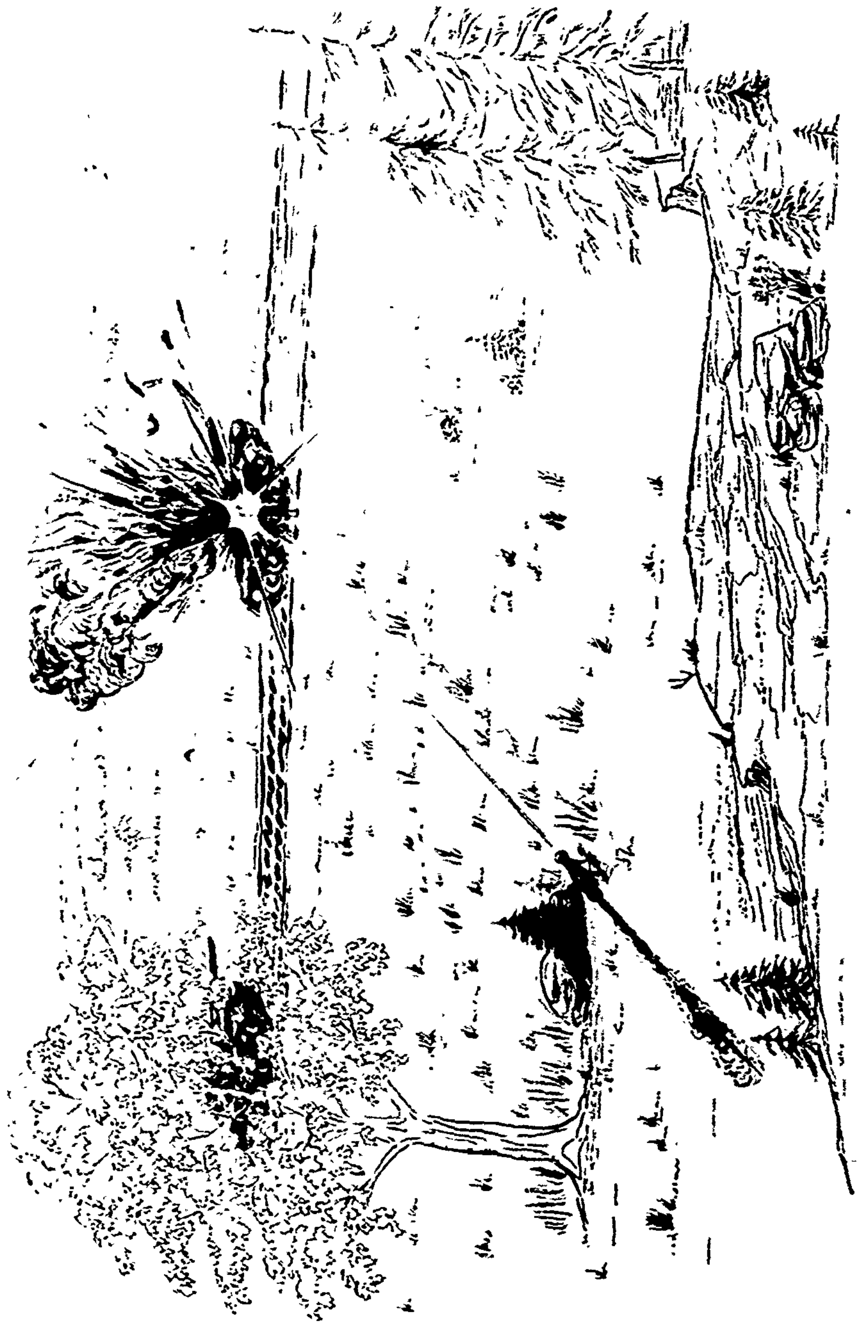

Frontispiece

Off Route Mine In Action

Page 1

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PROJECT NO. TS1-200

DATE: August 1960

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(C) OBJECT

The purpose of this study was to determine the feasibility of developing an effective, inexpensive, automatically triggered, remotely emplaced anti-tank weapon for infantry troops, using standard 3.5 inch M20A1B1 rocket launcher and M28 or M35 round.

(C) INTRODUCTION

Under Project TS1-200, "Mines and Accessories", this Arsenal has been engaged in determining the feasibility of Off-Route Mine Systems as part of an over-all program of investigation of low density minefields.

The need for Off-Route Mines and/or low density minefields has been expressed in meetings with CONARC and the Corps of Engineers.

This Arsenal's current low density minefield program is quite extensive and covers several complex systems which will require substantial amounts of time and funds to develop. In view of this a program to determine the feasibility of developing a <u>simple</u>, <u>inexpensive</u> system which could be developed at low cost and in a short time was conducted.

The development of such a system would be highly desirable since present AT warfare equipment involves buried mines which disable a tank only when the vehicle passes directly above it.

Modern tactical concepts, specifically those that call for minimum amounts of equipment and highly mobile striking forces require revisions of both mining techniques and mines themselves, since:

1. Significant burial times and labor are required to implant effective minefields.

2. Large quantities of mines are necessary to assure effective route denial. (M6-M15 type.) Moreover, it is impractical to mine large portions of paved roads and highways with present anti-vehicular mines because of concealment problems as well as the excessive amount of manpower and specialized construction equipment required to break through paved surfaces.

It is believed that an automatic antitank weapon as described herein would be highly desirable to give the Infantry man his own off-route mining capability to deny avenues of approach to the enemy.

Additional studies are being conducted at the Arsenal to determine the feasibility of using the bazooka rocket with a zero length launcher which has some advantages in weight and cost saving along with more ready adaptability for camouflage as compared to the complete bazooka system. Should such a system prove feasible it could then conceivably be developed as a mine system which could be used both by engineer and infantry personnel.

(C) CONCLUSIONS

1. A highly effective, inexpensive and reliable off-route weapon system can be readily developed in a short period of time at a low cost.

2. The various components of the proposed system, i.e., electronic control unit and pressure sensitive switch used during the feasibility study proved to be highly satisfactory.

3. The feasibility study model and design can be readily developed into a production model.

(C) RECOMMENDATIONS

1. It is recommended that the system described herein which will permit use of the M20A1B1 3.5" rocket launcher in the dual purpose of shoulder fired weapon and off-route mine be developed.

2. Continue investigations of a zero length launcher system for use solely in off-route mining applications.

(C) GENERAL SYSTEM DESCRIPTION

The system which was designed and tested is comprised of a 3.5" rocket launcher M20A1B1 modified to permit electrical and mechanical attachment of an Off-Route Accessory Kit. The accessory kit consists of an electronic control unit, a detection device and the necessary wiring. Figure 1 depicts the bazooka as modified for use in this application.

(C) DESCRIPTION OF COMPONENTS

A description of the major components in the system follows:

a. Bazooka Launcher: The bazooka launcher used for Off-Route applications is a standard launcher which must be modified prior to arrival in the field to accept the accessory kit. This modification permits the bazooka to be operated as a shoulder fired weapon or as an Off-Route mining device. Modifications required to the bazooka launcher for this purpose are relatively simple (and for tactical use could be performed in a maintenance depot) and consist of:

(1) Insertion of a plug-in connector at the cover plate.

(2) Rerouting of some of the launcher wiring to this plug.

Above is shown a full length modified launcher,rocket,3.5 inch, M20A1B1 with bipod and monopod assembly. In center is shown the modified launcher with the Electronic-Control Unit attached. Below is shown the complete off-route system, including field wire leading to "TS" pressure sensitive switch wire. "TS" wire shown in foreground for illustration.

FIGURE 1

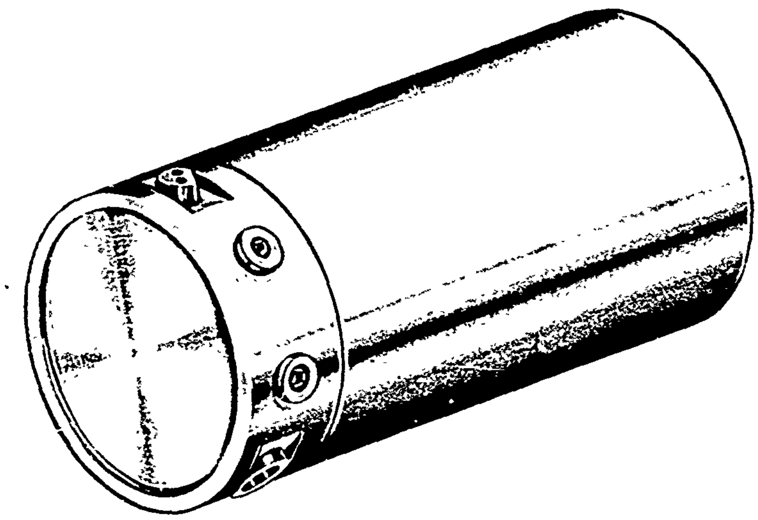
b. Electronic Control Unit: The electronic control unit (Figures 2 and 3) consists of a replaceable battery, a transistor switch and an operational check circuit.

(1) Battery: The battery used is a high drain battery of the flashlight type except that it is capable of operation at temperature extremes ranging from -65°F to +110°F.

(2) Transistor Switch: The transistor switch is incorporated in the circuit as a switching device for the purpose of negating the effects of increased resistance in the circuit should it occur.

(3) Operational Check Circuit: The operational check circuit allows the user to check out the system prior to installation. Although not designed into the device used in the study, the check circuit can readily be incorporated into a tactical unit to provide a go-no-go type of signal.

c. Detection Device: The detection device consists of a pressure actuated wire approximately 5/8 inches wide by 1/8 inches thick, (type "TS"). It can be obtained or provided in various lengths. This pressure sensitive wire is very similar to that used in actuating supermarket doors.



ACTUAL SIZE

ELECTRONIC - CONTROL UNIT

Figure 2 Control Unit - Artist's Concept

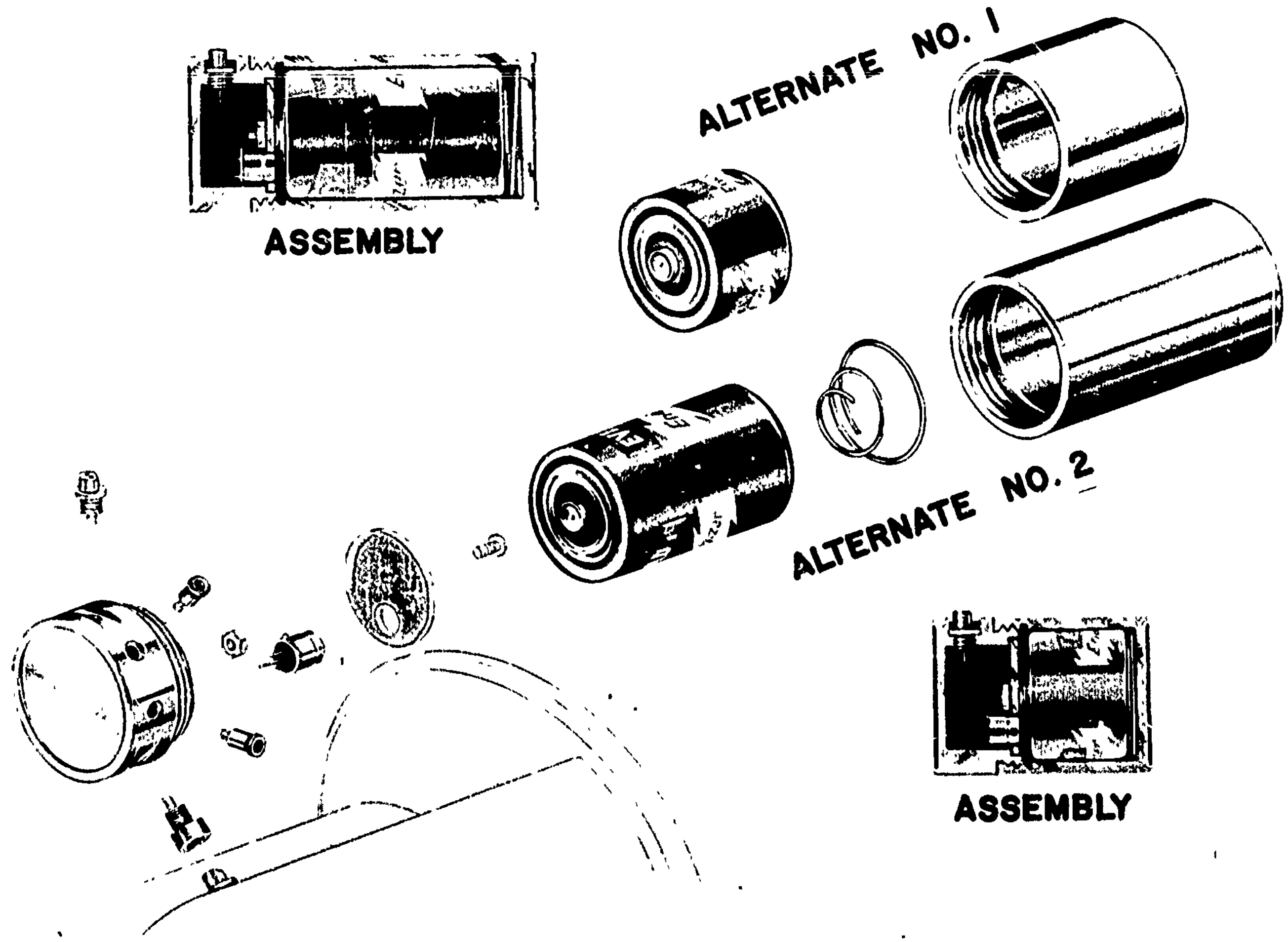


Figure 3. Firing Control Unit - Exploded View

Three wires were initially considered but the wire described above shows the most promise for immediate application. Figure 4 depicts this wire.

d. Additional accessories: The only additional accessory required is a length of wire to connect the pressure tape switch to the bazooka launcher.

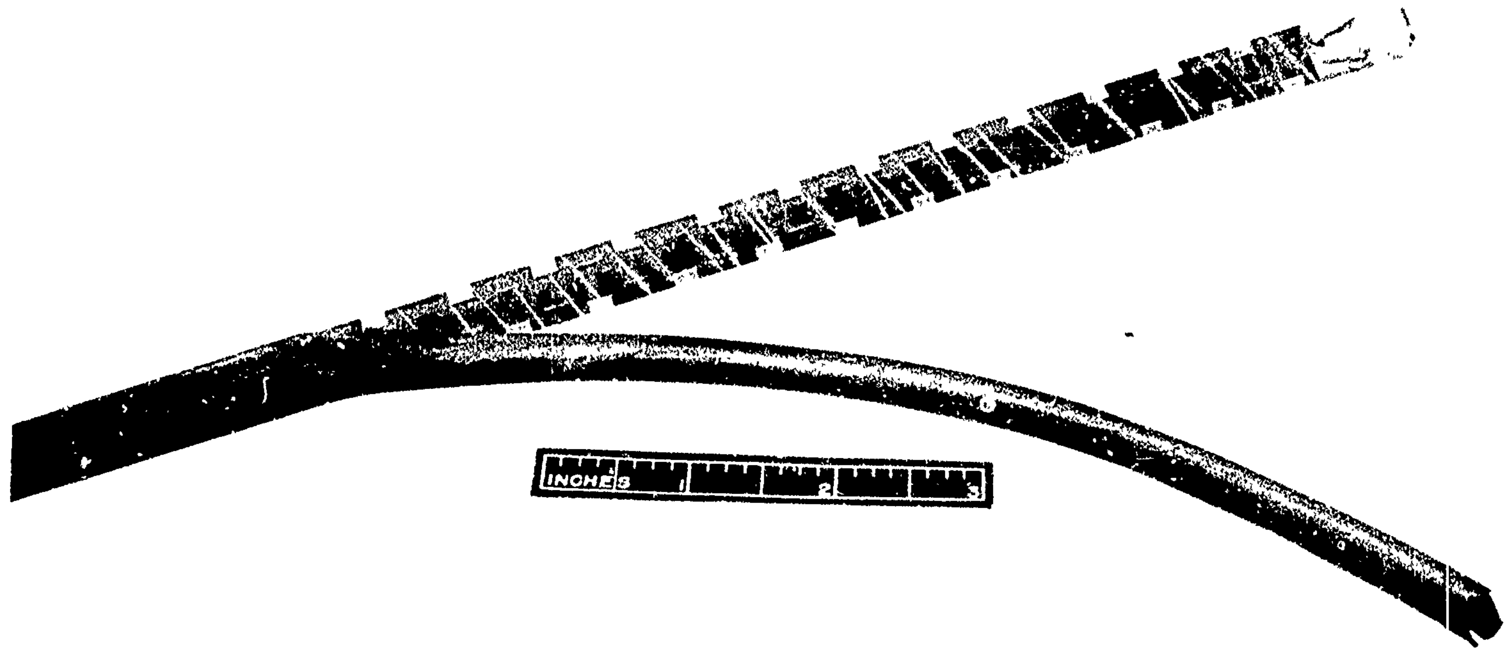


Figure 4. "TS" Pressure Wire - Note Covering Removed

(C) METHOD OF OPERATION

To operate the system, the accessory kit is attached to the bazooka launcher and necessary connections made by means of plug-in jacks. The pressure sensitive tape is placed across the road and the bazooka launcher is aimed in azimuth along the detection devices and in elevation approximately 3 ft. up from the road or at the desired point of impact. The pressure sensitive device is then attached to the length of electrical field wire which in turn is plugged into the electronic control box. At this time checkout is conducted, then the rocket is inserted in the launcher in the usual manner for shoulder firing, and the safety switch of the launcher is placed in the fire position. The system is then ready for operation. When a vehicle crosses the pressure tape the rocket is then fired. The system can be recovered and safed if desired by reversing the safety switch.

It is estimated that the total operation described above can be accomplished in approximately 2 minutes by 2 men.

Figure 5 is an artist's concept of setup and sequence of operation. In actual use the bazooka system can be readily camouflaged and the pressure switch can either be buried or

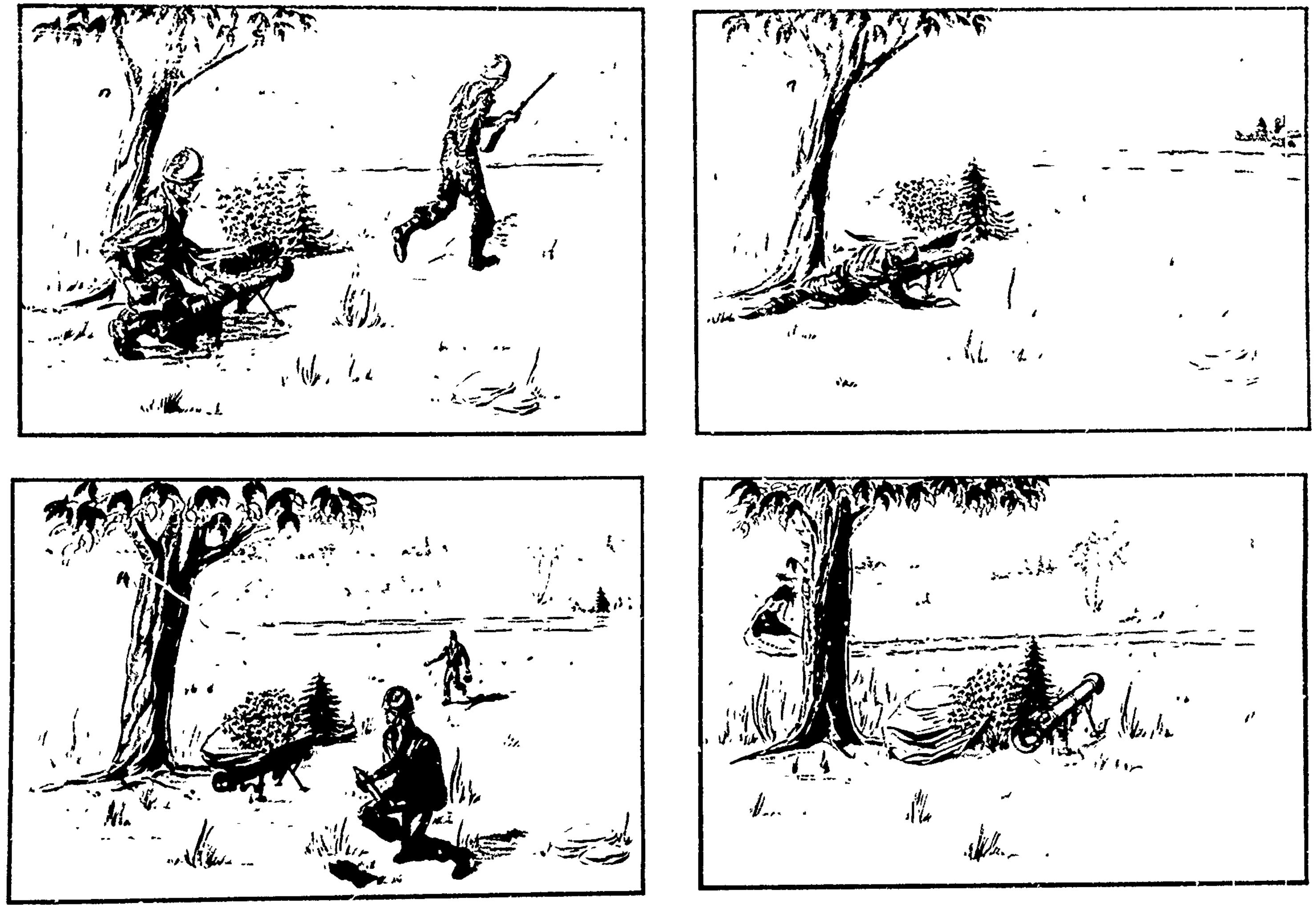


Figure 5. Artist's Concept of Off-Route Mine Setup

left on the surface, dependent upon soil conditions or road surface. Figures 6 and 7 show a camouflaged launcher and tape pressure switch.

In actual use, if desired the system can be protected by standard APERS mines or set to simultaneously fire an M18 fragmentation mine at time of actuation by a vehicle.

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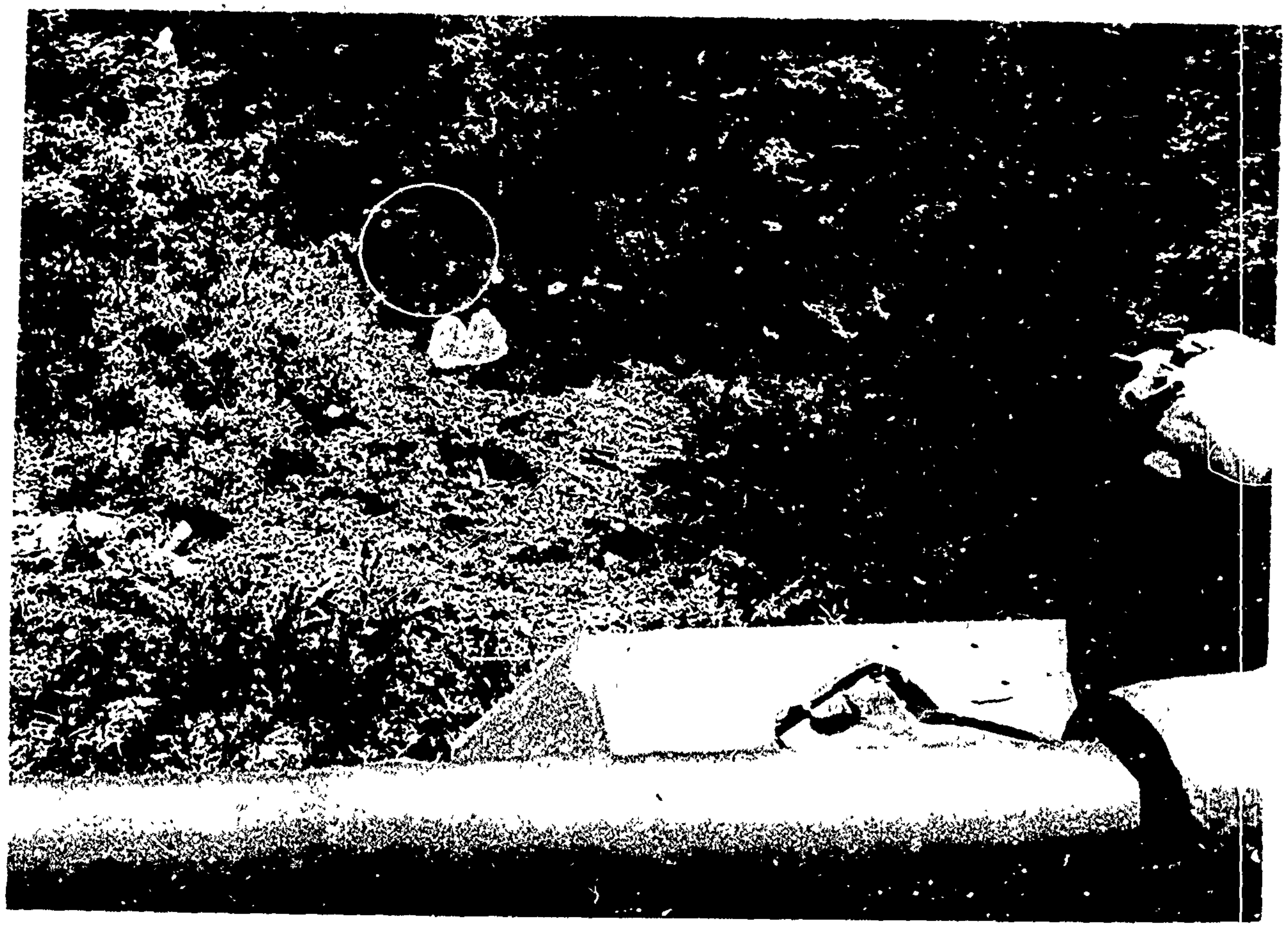

Figure 6 Camouflaged Off-Route Mine as Viewed from Tank. Note: Rocket Launcher is circled and under this condition tank would have been hit at time photograph was taken.

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Figure 7. Pressure Wire Buried in Dirt Road. Circled White Tag Denotes Location.

(C) SYSTEM CHARACTERISTICS

1. The system tested and analyzed during the feasibility study displayed the following characteristics.

a. The system has a probability of hit (against an 8x19 rectangular target) approaching unity for target speeds ranging from 6 mph to 32 mph at a 100 ft. range. At slower speeds the P_H degrades to 50% for a stationary target. In the development model, the slow speed limitation could be improved by addition of an optional delay circuit or by off-setting the detection device in terrain where vehicle speed is limited. Figure 8 covers P_H vs. target vehicle. Appendix II discusses target engagement parameters.

b. The system operates effectively against targets crossing the detection device in either direction.

c. Particularly in road applications, impact of the rocket will be at 0^o obliquity, thereby maximizing the P_K.

d. The electronic control unit proved to be a reliable device capable of repeated use.

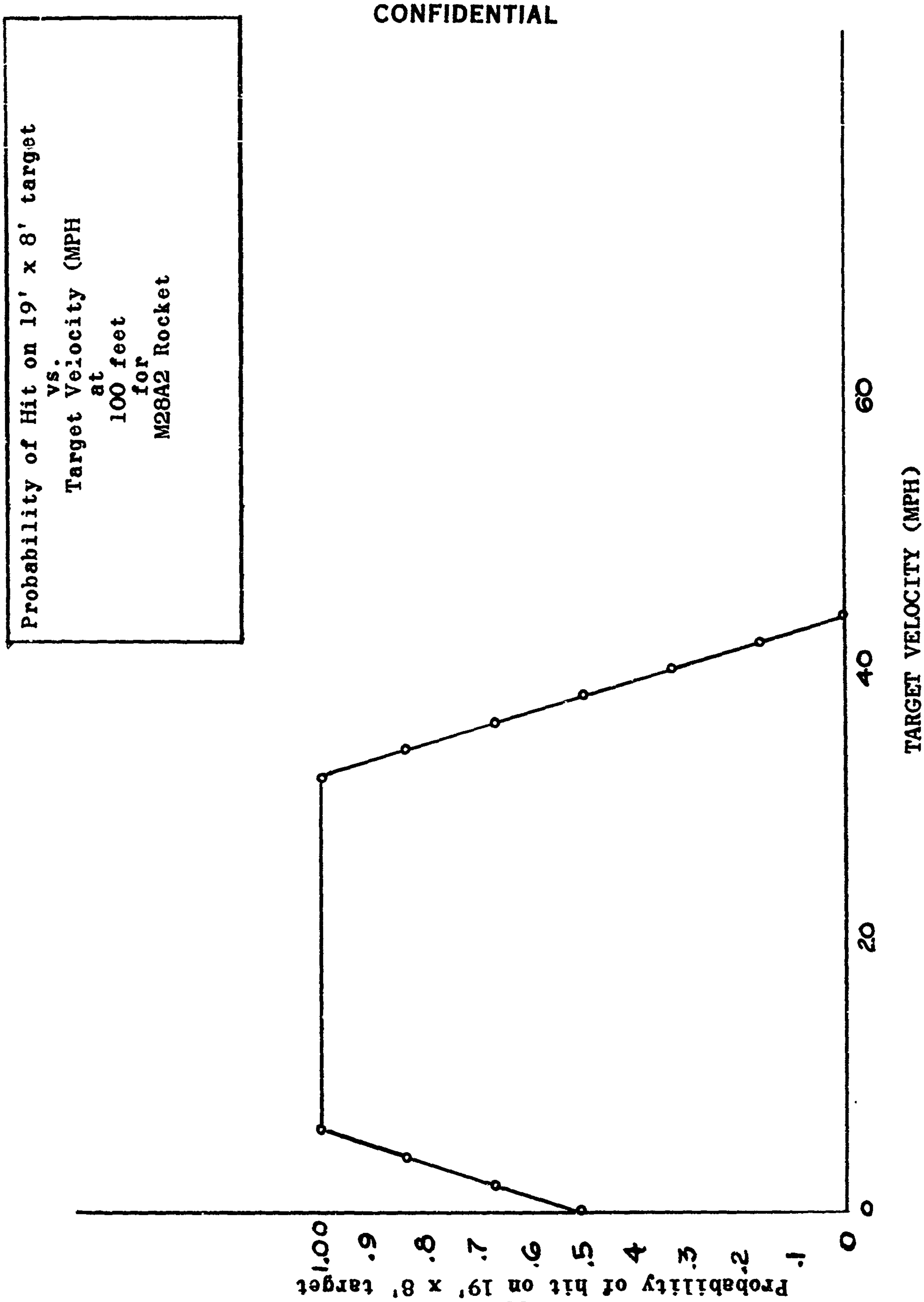
Probability of Hit on 19' x 8' target
vs.
Target Velocity (MPH
at
100 feet
for
M28A2 Rocket
0
20
40
60
TARGET VELOCITY (MPH)
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.00
Probability of hit on 19' x 8' target

Figure 8

e. The detection device, ie, the pressure wire was actuated under a wide variety of conditions of vehicles (automobiles to tanks), soil conditions (sand, mud, gravel, concrete) and target speeds (2 mph to 40 mph). The pressure wire was also satisfactory when buried.

f. Although no temperature, environmental and rough handling tests were conducted on all components, their design is such that no major problems should be encountered. The prime advantage of the system is that no moving parts, which are susceptible to damage, are required.

(C) THE TEST PROGRAM

A limited test program was conducted at the Arsenal to evaluate some of the characteristics of the system proposed. This program was primarily conducted to determine the following:

a. The durability and reliability of several prototype detection devices when activated by a tank or car under varying ground conditions.

b. The reliability and reusability of the electronic control unit along with the complete system.

c. The probability of hit at various ranges, on vehicles operating at various speeds.

d. The ease with which the system can be set up and effectively camouflaged.

e. The reliability of individual components such as battery, transistor, etc. The tests on these individual components are not covered in this report but will be subject of a detailed report to be published at a later date. The tests proved these components adequate.

To permit conducting tests in Arsenal areas where live rocket firings are not permitted, a photographic technique was devised for determining proper system functioning. This technique consisted of photographing the target through the bazooka launcher, the camera being actuated by the detection device through a delay circuit. This circuit provided a delay comparable to that of the rocket flight time to the point of impact at a particular range. The field of view of the camera was a circle 3.25 ft. in dia. at 50' and 7.5 ft. in dia. at 100 ft. which is more than the dispersion of the M28 Rocket. By this means therefore, the round dispersion was superimposed on the tank area covered to verify calculated hit probability.

Figure 9 shows this photograpnic simulator set-up and figure 10 shows typical photographs of "hit" targets.

Table I summarizes data obtained in various trials on different surfaces and with varying vehicle speeds and ranges. The tests were conducted with two pressure sensing switches type "AA" and type "TS". The TS wire proved satisfactory generally under all conditions although several failures occurred with the AA wire. The tests substantiated the analytical data on the hit probability and indicated the system to be most feasible. The reliability of the control unit was well proven and it was found that

TABLE I

SUMMARY OF TESTS RESULTS

Vehicle Type	Speed-MPH	Surface	Simulated Rocket	Range (ft.) (By wire type)		Pressure Wire Actuation and Photo Simulation (By wire type)	
				AA	TS	AA	TS
Auto	5-40[1]	Concrete	M35		50		yes
Tank	20-25	Concrete	M35	100	50	yes[2]	yes[2]
Tank	4-6	Concrete	M35	100	50	yes[2]	yes
Tank	11-14	Concrete	M35	100	50	no	yes
Tank	19-26	Concrete	M35	100	50	no	yes
Tank	4-6	Gravel	M35	50	100	yes[2]	yes
Tank	15-18	Gravel	M35	50	100	no	yes
Tank	24-28	Gravel	M35	50	100	yes[2]	yes
Tank	2-4	Mud on Sand	M28	100	50	yes	yes
Tank	7-[illegible]	Mud on Sand	M28	100	50	yes	yes
Tank	12-16	Mud on Sand	M28	100	50	no[3]	no
Tank	4-6	Sand	M28	50	100	no	yes
Tank	7-10	Sand	M28	50	100	no	yes
Tank	11-14	Sand	M28	50	100	no	yes
Tank	11-14	Sand	M28	50	100	yes[4]	yes[5]

NOTES:

1. Tests conducted at 5,10,15, 30 and 40 MPH.
2. These wires were permanently shorted after use, hence not reusable.
3. Wire functioned satisfactorily after test when actuated by hand.
4. 2 runs conducted
5. 4 runs conducted
6. Tests were also conducted with satisfactory results with both "AA" and "TS" wires on concrete and sand using static pressure of one tread, half track coverage, both at slow speed and stopped tank.

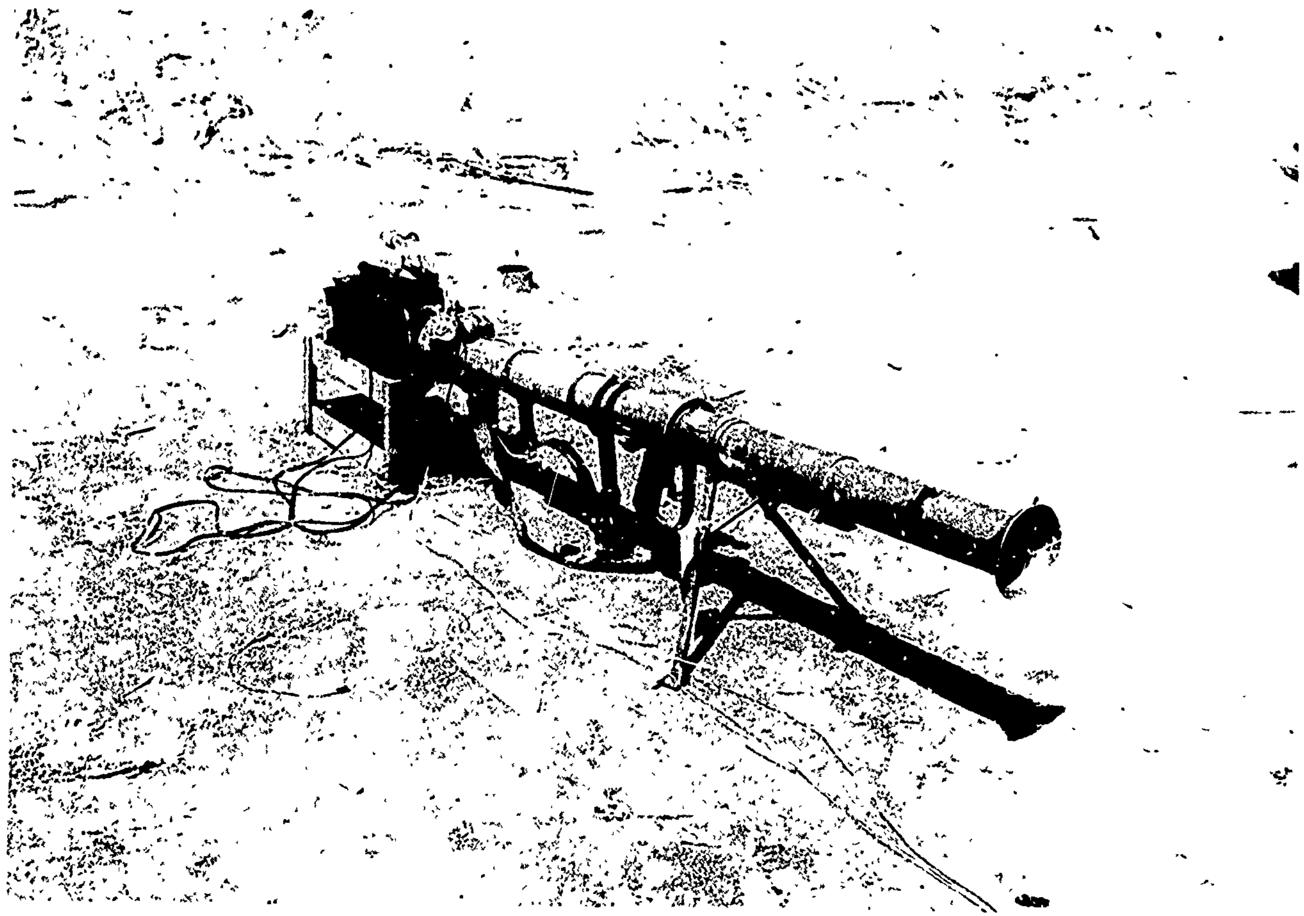

Figure 9. Off-route launcher system test set-up complete with Electronic Control Unit, hook-up wire leading to switch detection wire, and camera assembly.

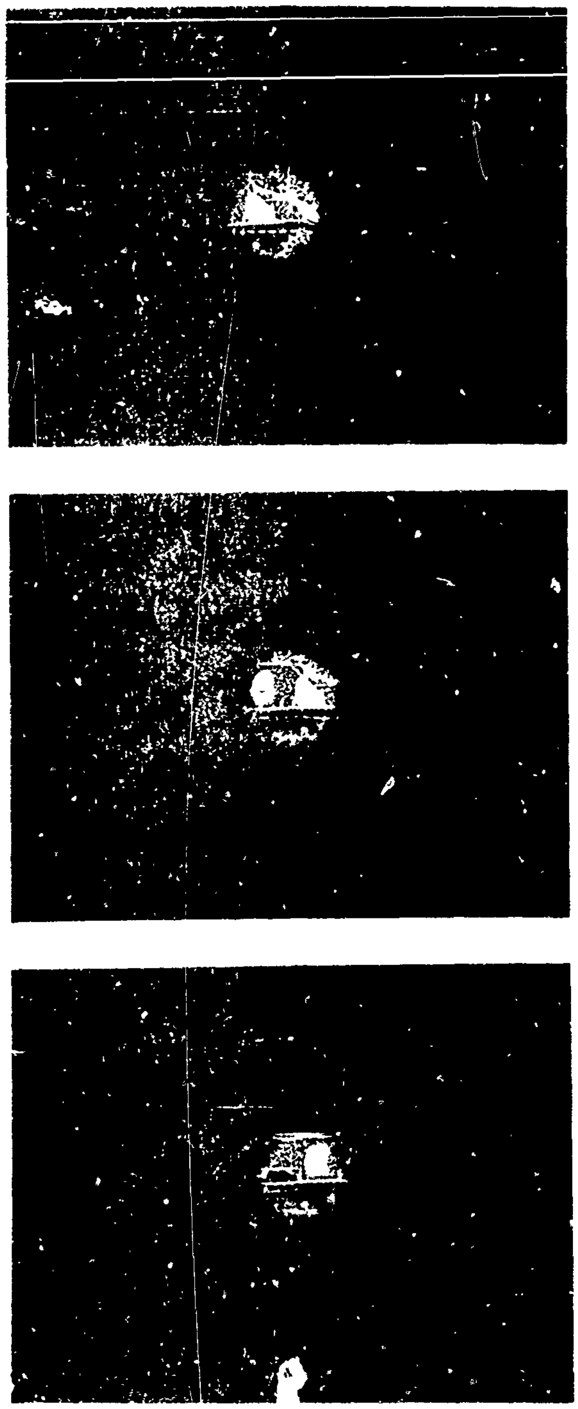

Figure 10. Photographic Test Results Taken on the Gravel-Hard-Earth Roadway using a Simulated M35 Rocket and "TS" Wire. From top to bottom, the M4A3 Tank used was travelling at 5, 15, and 25 mph respectively. Range was 100 feet.

it could be used repeatedly, in fact, during the feasibility study one control unit was actuated 340 times.

To further substantiate photographic simulation, 5 bazooka rockets were fired against moving vehicles. Four of these had inert warheads and were fired against a tank moving at speeds ranging from 5 to 10 mph. In all cases the tank was hit. Figure 11 shows a typical round hitting the tank.

One round with a live warhead was fired against a truck which was towed at approximately 5 mph. Figure 12 shows the damage to the truck after being hit.

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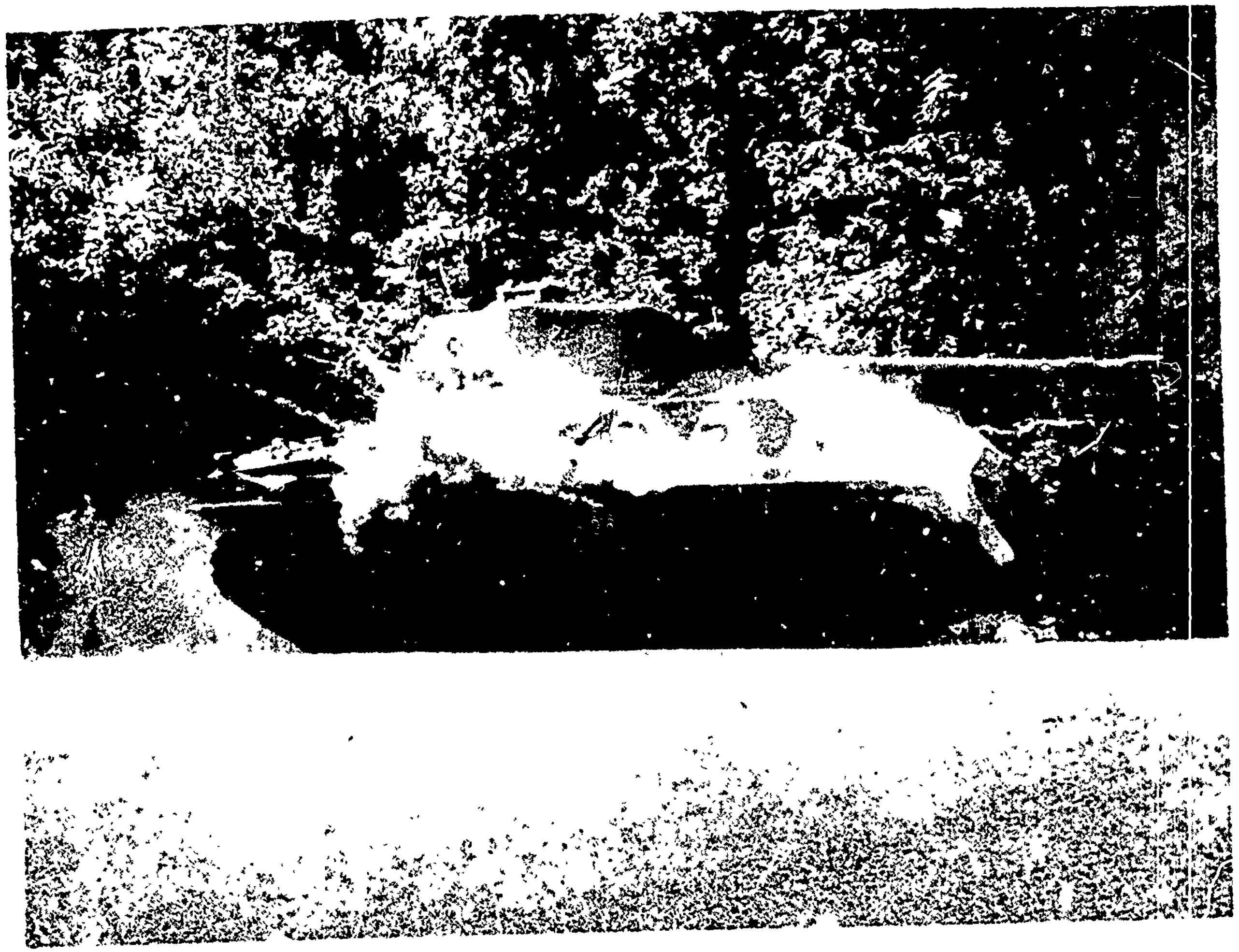

Figure 11. Inert M28A2 Bazooka Round Striking Tank at 50 Ft. Range. Tank Travelling approximately 5 MPH.

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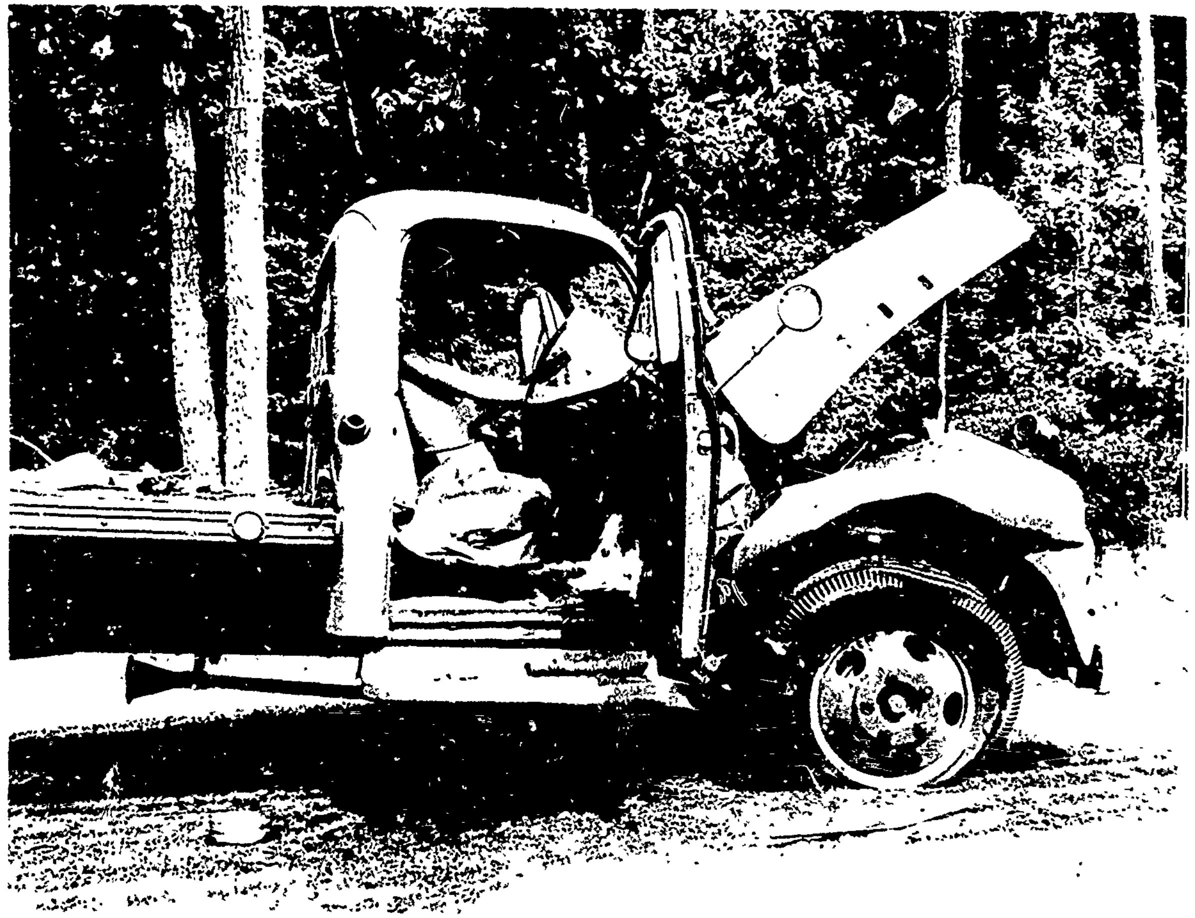

Figure 12. Results of M28A2 Round with HEAT Warhead Impacting 1-1/2 ton truck at 50 feet range and speed of 10 MPH.

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(C) THE SYSTEM PROPOSED FOR DEVELOPMENT

The system proposed for development would be similar to that used during the feasibility study except ruggedized for troop use. A checkout circuit of the go-no-go type will be added to the control unit and weatherproof connections used throughout.

Modifications to the bazooka launcher would be recommended as a result of the development program to permit dual use by infantry troops. A kit consisting of the electronic control unit, a length of field type wire with proper connectors and a length of pressure wire 25 feet in length would be provided. It should be noted that if recovered, the system (excluding detection device in some cases) is reusable.

It is estimated that this system can be developed to completion of engineering tests in a period of one year at a cost of $75,000.

APPENDIX I

(C) APPENDIX I

GENERAL DISCUSSION OF COMPONENTS SELECTED FOR USE

An anti-vehicular off-route system requires three (3) basic components:

a. A sufficiently lethal and accurate weapon, including both the warhead and warhead delivery system.

b. A target detection device.

c. A control unit capable of automatically firing a weapon in response to detector operation.

Warhead and Warhead Delivery System

Two (2) weapons were initially considered for off-route application; the Light Weight Infantry Assault Rocket Weapon (LAW) currently under development, and the standardized 3.5 inch Rocket Launcher, M20A1B1 ("Bazooka") with the M28 or M35 rounds.

The Bazooka was selected for use since:

a. The Bazooka is standardized and large quantities are available for issue to Infantry Units on a T. O. & E. basis without necessity for additional production.

b. The Bazooka is electrically operated.

c. The Bazooka is considerably more lethal than the LAW because of use of a larger warhead.

There is, however, no reason that the LAW could not be modified for use in a similar role.

Table II below lists rocket and warhead data obtained from Ordnance Committee Item 35924.

TABLE II

	Type Round	
	M35	M28A2
Penetration (From Board 3 Report 2591A, 30 Sept 54)		
6-1/4 inches Homogeneous Armor at 59.4°	100% complete	----------
6-1/4 inches Homogeneous Armor at 64°	penetration 20% complete	----------
5 inches Homogeneous Armor at 64°	60% complete Penetration	----------
Maximum Range	1310 yards	936 yards
Accuracy	Approx 1-1/2 mils	Approx 1-1/2 mils
Velocity	485 vt/sec	320 ft/sec
Hit Probability 7-1/2 ft x 7-1/2 ft at 300 yards	80%	20%
Weight	7.3 lb.	9.1 lb.
Weight of HE	1.5 lb.	2.0 lb.
Temperature limits	-40°F to 125°F	-30°F to 120°

Note: The M35 Rocket burns entirely within launcher from -40°F to 135°F. The M28A2 burns forward from muzzle of launcher at lower temperatures.

Information received from Rock Island Arsenal on 8 August 1960 indicates that approximately 195,000 launchers are in stores. It is also estimated that there are seven million M28 rounds in stores. These bazooka rounds are electrically ignited by actuation of M1A1 or M2 squibs with a hand-operated magnetic trigger generator.

Target Detection Device

Several remote target detection techniques possess potential for off-route application, including infra-red, accoustical, electro-magnetic and nuclear radiation devices. Investigations underway at Picatinny and other agencies indicate that considerable design and engineering is necessary in order to satisfactorily develop one of these techniques. Accordingly, remote detection techniques were discarded for the present.

As an alternative, it was found that pressure sensitive electrical wire could be purchased from at least two (2) vendors, and initial evaluation of the wire showed that satisfactory operation was achieved in mud, gravel, hard pavement and sand. Results obtained to date indicate that little further development is required to obtain wire capable of operating satisfactorily under the conditions tested to date. Operations under climatic extremes requires further evaluation and possible development. In addition, miniaturized wire will require a development effort to achieve a design compatible with satisfactory manufacturing techniques.

Electronic-Control Unit and Launcher Modifications

The Control Unit shown in Figure 4 was designed to allow use of the launcher as an automatically actuated system without disturbing the option of using launcher as a manually fired weapon. This dual function is continuously and readily interchangeable depending only on tactical requirements.

Mechanical design was based upon converting the launcher from manual to automatic operation simply by plugging in the control unit. Manual operation is regained by unplugging the control unit. The design also allows ready replacement of batteries.

Modifications of the launcher were limited to the minimum required for electrical and mechanical attachment of the control unit, and consist of installation of a jack-type switch to the Latch Group Assembly Cover Plate, and connection of launcher wiring to this switch. The manually operated trigger mechanism is electrically isolated when the control unit is plugged in. Alternatively, new cover plates could be designed and manufactured which integrally incorporate the control unit, with selection of automatic or manual operation achieved by operating a selector switch.

The electrical design of the control unit was based upon fulfilling the following requirements:

a. To reliably fire the M1A1 or M2 squib used in the rocket motor.

b. To serve as a fire control system for use with various types of detectors which ultimately may be developed.

c. To operate reliably in the event of poor connections or weak input signals from the sensing element.

d. To provide a relatively high current source over wide temperature extremes.

e. To provide sufficient current to permit checking for operability prior to emplacement.

The transistor-switch was incorporated to fulfill requirements (a), (b), and (c), with the transistor circuit serving to provide sufficient output current for squib firing for resistances of up to 100 ohms in the input circuit. The battery fulfills requirements (d) and (e).

In particular, the use of a replaceable, high drain battery was selected over a low drain, long shelf life battery such as a solid electrolyte battery for a number of reasons:

a. Comparatively, the energizer battery costs $0.37 compared to $25.00 for a state-of-the-art solid electrolyte battery.

b. The high drain battery permits operational check-out at time of emplacement.

c. The use of a low drain battery would entail charging a firing condenser over a long period of time. The ability to retain a charge on a condenser is subject to failure particularly under adverse service conditions. In addition, operational check-out of a low drain system is not possible immediately prior to emplacement; hence, the reliability of any particular emplacement would be jeopardized by the use of faulty equipment.

d. Flashlight batteries are provided to troops; hence in the event of faulty batteries, replacements can be obtained from unit supply channels. Ordinary flashlight cells can be used when extreme temperatures will not be encountered.

e. The high drain system is suitable for re-use without a delay for recharging.

f. The high drain system will be required for more sophisticated detectors which will require continuous power.

g. Limited operational life tests and shelf-life tests on the battery have been conducted and will be reported separately . These tests show the battery would have an emplacement life of at least three (3) months over the temperature range of -65^{o} to 110^{o}F; and would be capable of providing a power drain of two (2) milliwatts for a period of 40 days at $-65^{\circ}F$. Operation at higher temperatures and over longer time intervals is probable, but tests at Picatinny Arsenal and at the Signal Corps (Fort Monmouth) to specifically determine the limits have not been completed at this writing.

APPENDIX II

(C) APPENDIX II

TARGET ENGAGEMENT VS RANGE AND ROCKET TYPE

Calculations were made to determine the speed and range of targets which can be engaged by the 3.5 inch rocket at distances of 50 and 100 feet with the launcher aimed at the contact point, i.e., with no lead angle.

Neglecting the effects of dispersion or windage, the calculations indicate that for a 100 foot range all targets from 0 to 40 mph would be hit with an M28A2 Rocket and from 0 to 60 mph with an M35. For the 50 foot range all targets from 0 to 60 mph would be hit with either rocket. The above values assume a target length of 20 feet [a]

Figure ~~13~~ ~~&~~ 14 show complete results, and are based on:

(1) Initiation and acceleration time for M28A2 - 0.027 sec. [b]

(2) Initiation and acceleration time for M35 - 0.0155 sec. [c]

(3) Velocity of M28A2 - 320 fps [d]

(4) Velocity of M35 - 485 fps [e]

(5) Miss occurs for target advance of greater than 20 ft.

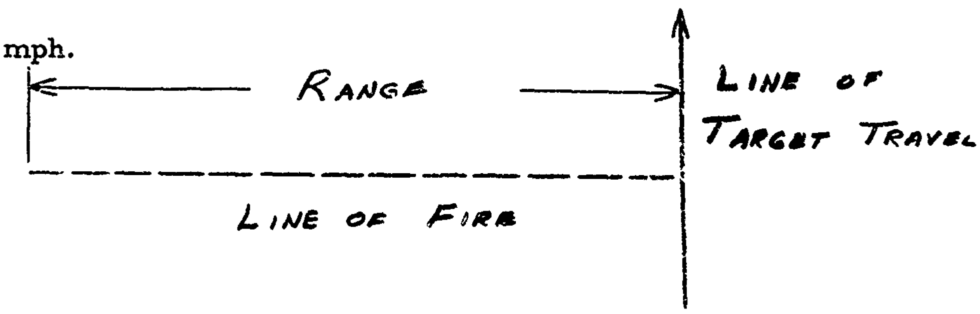
(a) M4A3 Tank - Length is given in TM9-759 as 20' 7".

(b) Initiation time of 0.007 sec obtained from experimental tests. Acceleration time of 0.020 sec obtained from Report A-10-A, ARGMA-AOMC, dated 1 April 1958.

SAMPLE CALCULATIONS

The point of impact was determined by summing the initiation time, acceleration time and flight time of the rocket and finding the amount of tank advance in that time.

A sample calculation is given below for an M35 Rocket at a range of 100 feet. Target length was assumed to be 20 feet and target velocity to be 60 mph.



RELATIVE POSITIONS OF TARGET & OFF-ROUTE SYSTEM

(Figure no. 1)

The total elapsed time from the targets contact with the sensing device to the instant of impact is broken down as follows:

(1)	Time to initiate M2 Squib	- 0.0025 sec (c)
(2)	Acceleration Time	- 0.013 sec (c)
(3)	Flight Time	- 0.206 sec (d)
	TOTAL TIME	0.222 sec

(c) Initiation time of 0.0025 sec obtained from experimental tests.

Acceleration time of 0.013 sec obtained from Report A-10-A, ARGMA-AOMC, dated 1 April 1958.

(d) OCM 35924 dated 24 June 1955.

(e) IBID

T.A. = (V) Tt)

where T.A. = Target Advance during interval between closing of switch wire and impact of target.

V = Target Velocity
= (60 mph or 88 fps)

t = Total Time of Rocket
= (0.222 sec)

T.A. = (88 fps) (0.222 sec)

= 19.5 feet

This indicates that the point of impact on the target will be 19.5 feet behind the point of contact with the sensing device.

DISPERSION

According to BRL Technical Note 363, dated May 1961, an M28A2 Rocket has a hit probability of one (1) for a 6 x 6 foot square at ranges up to 150 feet. Figure 15 giving hit probabilities was taken from BRL Note 363.

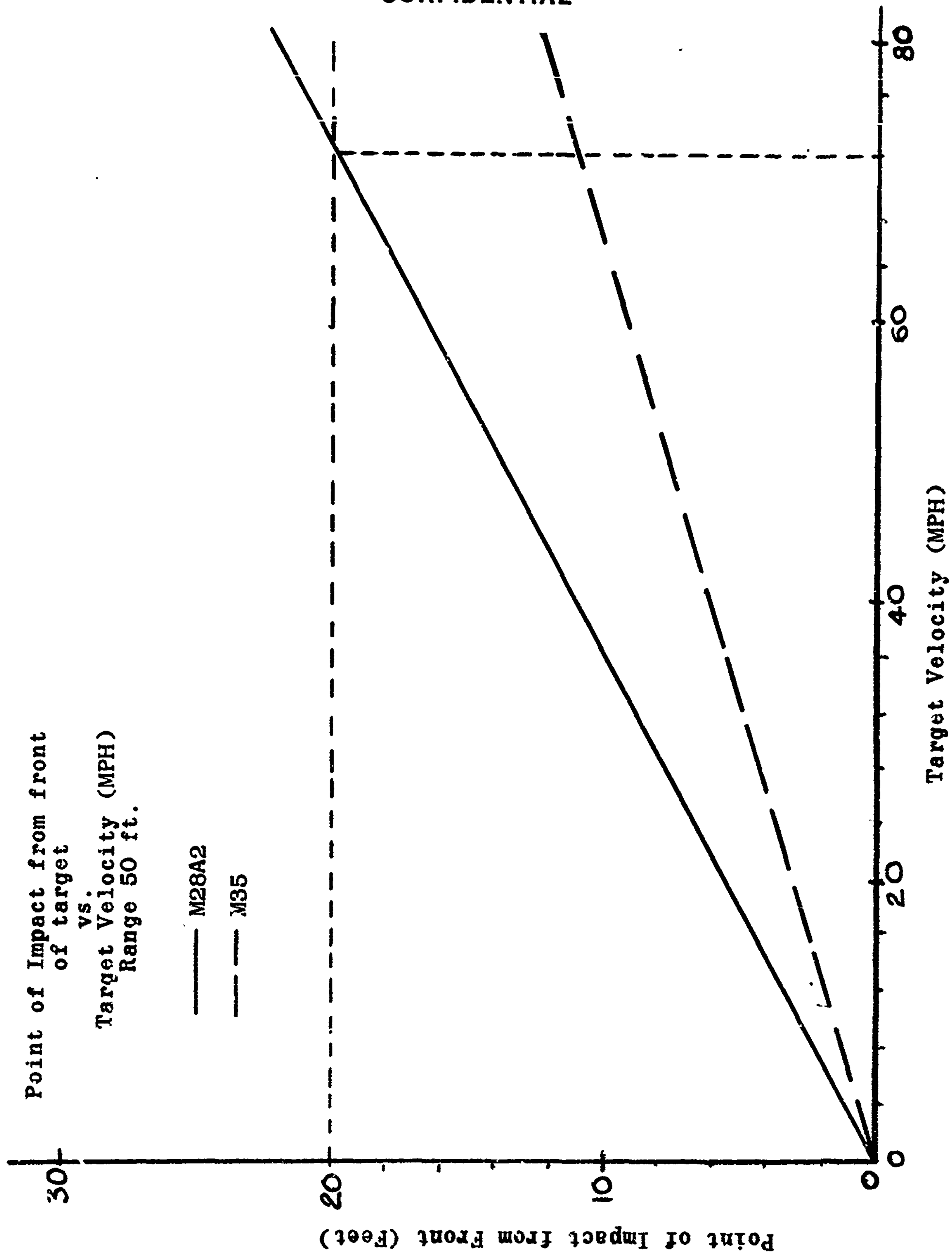
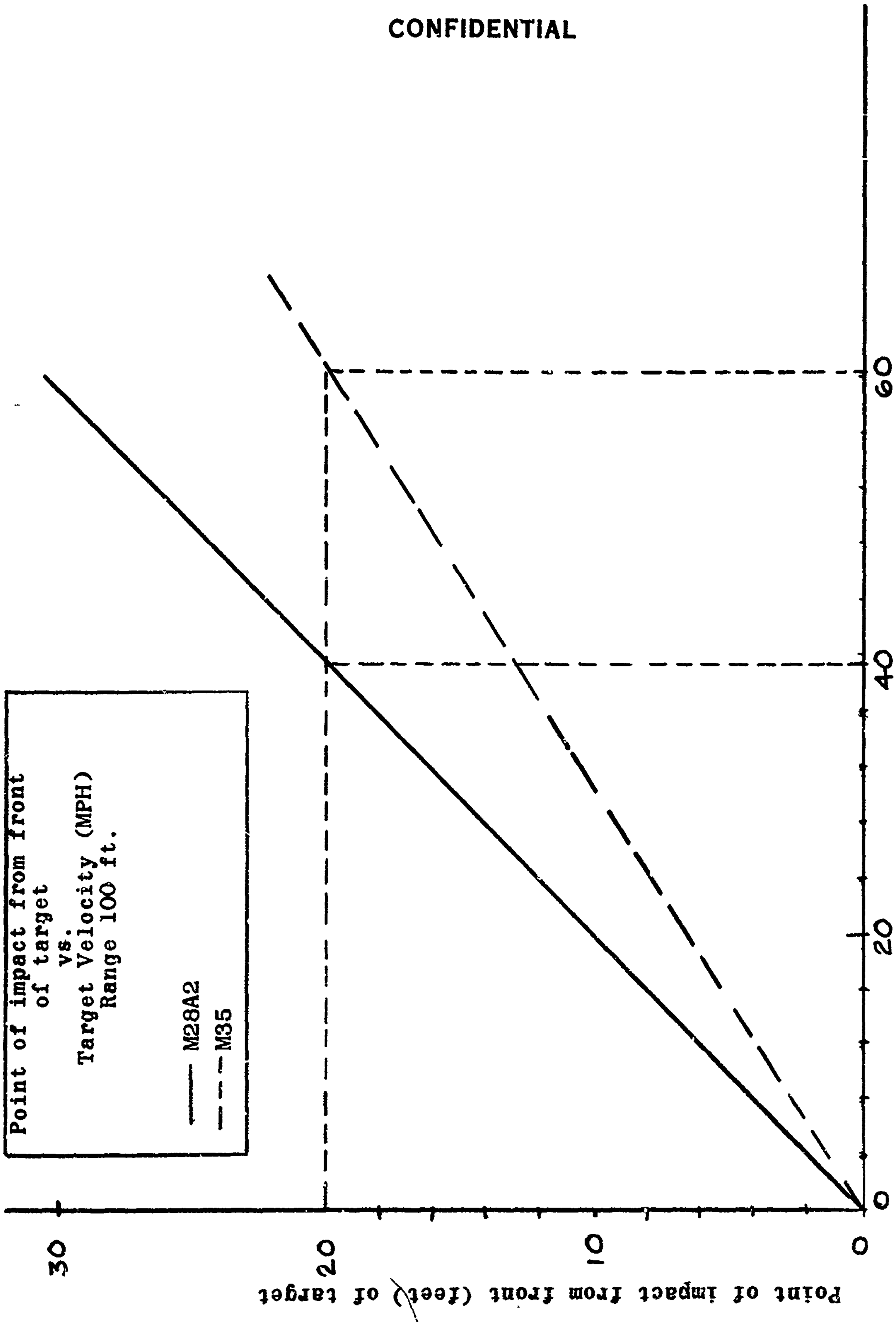
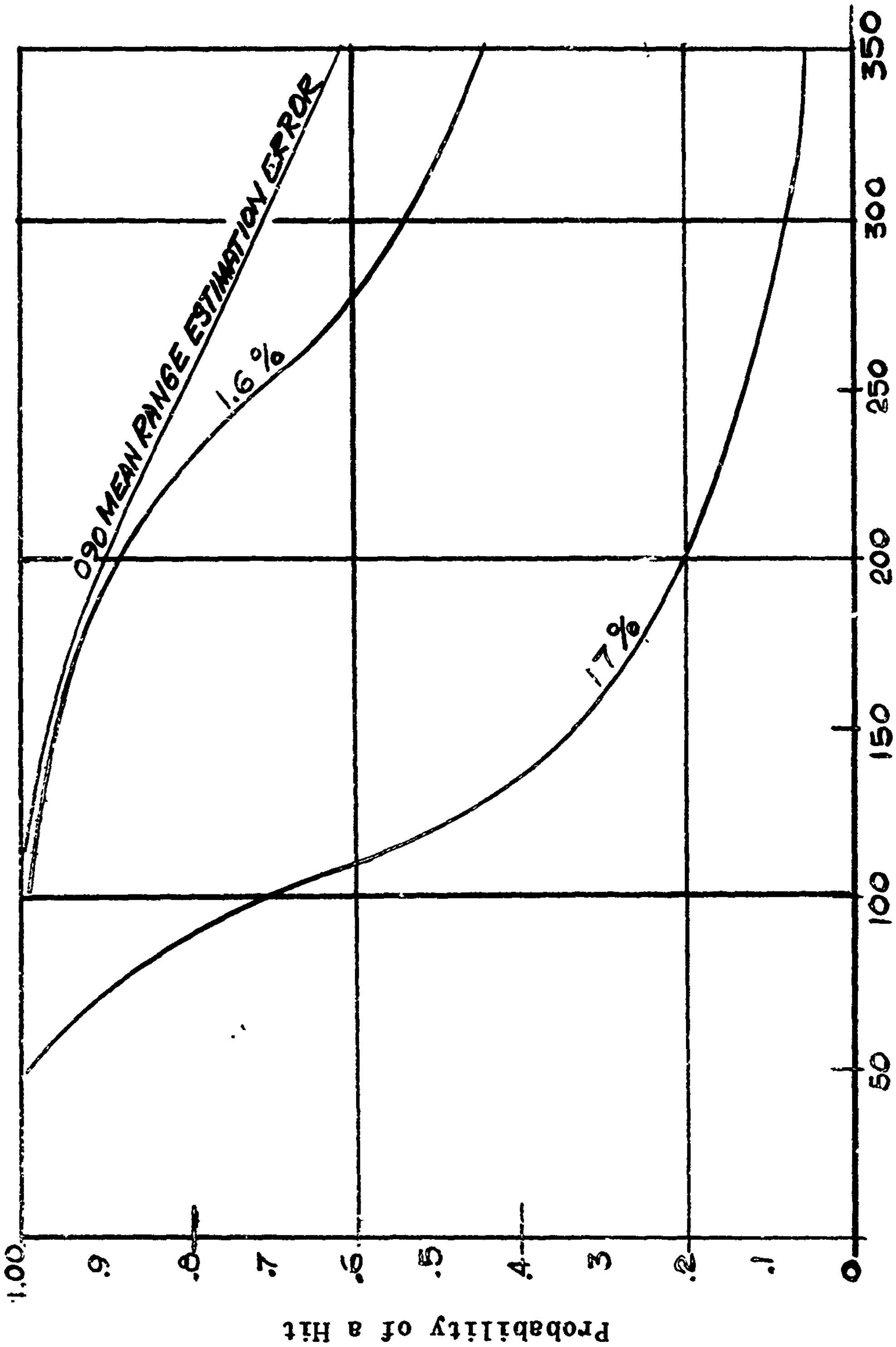

Point of Impact from front
of target
vs.
Target Velocity (MPH)
Range 50 ft.
M28A2
M35
Point of Impact from Front (Feet)
0
10
20
30
Target Velocity (MPH)
0
20
40
60
80

Figure 13



Target Velocity in MPH
Figure 14

3.5 Inch HEAT Rocket - Probability of a Hit on a 6'x6' Target



Range - Yards

Figure 15